UNITED STATES DEPARTMENT OF THE INTERIOR

NATIONAL IRRIGATION WATER QUALITY PROGRAM
INFORMATION REPORT NO. 3

Guidelines for Interpretation of the Biological Effects of Selected Constituents in Biota, Water, and Sediment

Zinc

Participating Agencies:

Bureau of Reclamation
U.S. Fish and Wildlife Service
U.S. Geological Survey
Bureau of Indian Affairs

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Zinc

Description

Zinc (Zn) is a lustrous white to pale-bluish-gray metal when freshly cut or polished, though it more commonly appears dull gray, owing to a coating of hydrated zinc carbonate that develops after extended exposure to the air. It is a relatively soft metal, having a hardness intermediate between that of gypsum and calcite. It is brittle at normal temperatures but is more malleable under low heat (100–150 °C). It melts at 419 °C and boils at 907 °C.

Pure metallic zinc is rarely seen in nature, for the element is highly reactive and forms a variety of white to pale-colored salts. Most of its compounds are water soluble, though the metal itself is not. Because of its high reactivity, zinc is commonly used as a coating over steel (galvanizing). The steel is thus protected, as corrosive agents preferentially attack the zinc coating. Also, for many centuries, zinc has been alloyed with copper to make brass. The most common zinc ore is sphalerite (ZnS), a yellowish to dark-brown cubic mineral, though some zinc also is produced from smithsonite ($ZnCO_3$) and from hemimorphite ($Zn_4Si_2O_7(OH)_2 \bullet H_2O$).

Occurrence

Mean total zinc contents in surface soil range from 17 to 125 mg/kg, and grand mean zinc for worldwide soils is calculated to be 64 mg/kg (Kabata-Pendias and Pendias 1992). Background concentrations of zinc in soils or sediments seldom exceed 200 mg/kg (Eisler 1993). In fresh water, the concentration is normally less than 40 to 60 µg/L (Taylor et al. 1982, Eisler 1993).

The most important artificial sources of zinc in the environment include electroplaters, smelting and ore processors, mine drainage, domestic and industrial sewage, road surface runoff, corrosion of zinc alloys and galvanized surfaces, and erosion of agricultural soils (Eisler 1993).

Summary of Effects

Zinc is an essential element for all living organisms, but elevated levels of zinc in the environment may be harmful near zinc-contaminated sites. Zinc is bioaccumulated by all organisms, even in areas of low zinc concentrations. Both deficient and excessive amounts cause adverse effects in all species.

Zinc is most harmful to aquatic life during early life stages, in soft water, under conditions of low pH, low alkalinity, low dissolved oxygen, and elevated temperatures (Eisler 1993). In contrast to its toxicity to sensitive aquatic organisms, zinc is relatively nontoxic to birds and mammals, and tissue concentrations are homeostatically controlled (Furness and Rainbow 1990, Eisler 1993).

Although tissue residues are not yet reliable indicators of zinc contamination, zinc poisoning occurs in birds when liver or kidney concentrations exceed 2,100 mg/kg dry weight (dw), and in mammals when levels exceed 274 mg/kg dw in kidney or 465 mg/kg dw in liver (Eisler 1993). In amphibians, the tissue values range from 33 to 150 mg/kg dw at uncontaminated sites (Hall and Mulhern 1984). A summary of biotic effect levels is presented in table 34.

Suter and Mabrey (1994) evaluated a series of toxicological benchmarks for screening

Table 34.—Summary of comprehensive biotic effects of zinc

[Note: Diagnostic levels for toxicity are not well established in *any* animal tissues because the zinc concentrations generally are homeostatically regulated]

Medium	No effect	Level of concern	Toxicity threshold	Comments/Explanation
Water (µg/L)	<30	30–110	110	30 µg/L is lowest chronic value for aquatic life (Suter and Mabrey 1994). Threshold value assumes chronic exposure at hardness of 100 mg/L (as $CaCO_3$).[1]
Sediment (mg/kg dw)	150	150–410	410	From Long et al. (1995); however, sulfides in sediment may reduce Zn toxicity.
Plants (mg/kg dw)	27–150	150–300	>300	Kabata-Pendias and Pendias (1992).
Invertebrates	—	—	—	
Fish (white sucker muscle tissue; mg/kg dw):	—	—	20	From Munkittrick et al. (1991), but this is lower than normal background (88) for whole fish (Schmitt and Brumbaugh 1990).
Birds (mg/kg dw):				
Eggs	50	—	—	J.P. Skorupa, unpub. data, 1996.
Liver/kidney	<210	—	>2,100	
Reptiles/amphibians	—	—	—	
Mammals (mg/kg dw):				
Kidney	<210	—	>274	Talmage and Walton (1991).
Liver	<210	—	>465	

[1] Zinc toxicity in water is affected not only by hardness but also by factors such as pH, temperature, dissolved oxygen, and alkalinity. Toxic effects may occur in sensitive phytoplankton, invertebrates, or fish life stages at concentrations in the "level of concern" range. In most of the West, hardness of more than 200 mg/L is much more common, and zinc would be less toxic under those conditions.

various contaminants for their potential effects on aquatic biota. In addition to the national ambient water quality (NAWQ) criteria, they provided secondary acute and chronic values, lowest chronic values (including those for fish, daphnids, nondaphnid invertebrates, aquatic plants, and all organisms), test EC20s, sensitive species test EC20s, and population EC20s. The values for water in table 34 are as follows: "No effect" is the lowest chronic value for all organisms; "Toxicity threshold" is the NAWQ chronic criterion (if established) or the secondary chronic value; and "Level of concern" is the range between the two other values.

Field Cases

Many studies have been conducted in recent years to investigate the toxicity of zinc and zinc-copper mixtures in effluents. Finlayson and Verrue (1980) and Finlayson and Ashuckian (1979) conducted long-term and short-term toxicity studies on Chinook salmon and steelhead trout, respectively, in order to estimate "safe" levels of zinc and copper for those species. Harrison and Klaverkamp (1990) also conducted an extensive study on the bioaccumulation of zinc, copper, and other metals in northern pike and white sucker from lakes near a smelter.

Three examples illustrate the potential impacts of zinc-contaminated mine drainage on the aquatic environment:

(1) Acid mine drainage from the Iron Mountain Mine near Redding, California, containing high concentrations of zinc and copper, caused numerous fish kills in the upper Sacramento River (Finlayson and Ashuckian 1979, Finlayson and Verrue 1980). Some of these occurred as far back as the early 1900's, but they became more frequent and more serious following the construction of Shasta Dam in 1944 and Keswick Dam in 1950. Finlayson and Ashuckian (1979) hypothesized that these dams had effectively diminished the “dilution effect” in the Sacramento River. Yet, the out-flows from these dams have also been used to purposely dilute elevated concentrations that are detected at downstream monitoring stations.

(2) Similarly, toxic concentrations of zinc and copper from the Penn Mine area in the Sierra Nevada of California caused sizable fish kills in the lower Mokelumne River Basin (Finlayson and Rectenwald 1978). During a fish kill in the Mokelumne River in 1958, zinc concen-trations of 1.4 milligrams per liter (mg/L) were measured 6.4 kilometers down-stream from the mine.

(3) In Canada, the effects of mixed mining wastes on fish were examined through integrated field sampling of water, sediment, invertebrates, and fish (Munkittrick et al. 1991, Miller et al. 1992). Miller et al. (1992), in particular, made an extensive study of the relationships between concentrations of zinc and copper in all these media in the Manitouwadge chain of lakes in northern Ontario. They found a correlation between zinc concentrations in invertebrates and in sediment but observed no such relationship with water concentrations. Neither did they find any relationship between zinc concentrations in fish tissue and those in invertebrates, although several lab studies had suggested that food and particulates are much more important sources of zinc than water (Patrick and Loutit 1976, Dallinger and Kautzky 1985, as cited in Miller et al. 1992). For both zinc and copper, the water concentration was a better indicator of metal concentration in fish tissue than the sediment or invertebrate concentrations in this field study. Miller et al. (1992) also reported reduced growth in females of white sucker after sexual maturation, decreased egg size and fecundity, no significant increase in fecundity with age, and an increased inci-dence of spawning failure at a waterborne zinc concentration of 156 mg/L and a sediment concentration of 6,397 mg/kg. In addition, they found kidney and liver concentrations to be better indicators of chronic zinc and copper exposure than muscle concentrations.

Abiotic Factors Affecting Bioaccumulation

Water

In natural waters, zinc occurs both in dis-solved form and as suspended particulates. Only the dissolved fraction is believed to be toxic to fish (Finlayson and Verrue 1980). Dissolved zinc assumes several different chemical forms in various inorganic and organic complexes. Zinc is present as Zn^{2+} in acidic waters and $ZnOH^{+}$ in soft waters. According to some studies, zinc is also present as a toxic "aquo ion," $(Zn(H_2O)_6)^{2+}$, almost exclusively in fresh water (Campbell and Stokes 1985). Softer water is also known to increase the toxicity of zinc in fish, and ambient water quality criteria are based on water hardness (EPA 1991, 1992). Most of the zinc introduced into the aquatic environment is eventually deposited in sediments.

Bottom Sediment

Biological effects have not been associated with zinc concentrations of 50 mg/kg (dry weight) or less in sediments, but the available data suggest that sublethal effects may occur at zinc concentrations between 50 and 125 mg/kg (Long and Morgan 1990). Long et al. (1995) identified 150 mg/kg as a safe level for zinc and 410 mg/kg as a concentra-tion above which adverse effects are common. Although many of the data that were evaluated were for estuarine and marine sediments, Hull and Suter (1994) concluded that those screening levels also were appropriate for freshwater sediments until more specific guidelines become available. However, they also recommend that these concentrations be compared to local background levels when possible, and that concentrations within the background range should not be considered a problem.

Acid-volatile sulfides (AVS) in the sediment may combine with a portion of certain metals (Cd, Cu, Ni, Pb, and Zn) and render that portion unavailable and nontoxic to biota (Di Toro et al. 1992). In order to assess the effects of acid-volatile sulfides on metal toxicity, the AVS is extracted from sediment with hydro-chloric acid, and the metal concentration that comes with it is called the simultaneously extracted metal (SEM). All SEMs that would contribute appreciably to the total SEM are measured and totaled (Di Toro et al. 1992). *If* the sediments are not fully oxidized (Adams et al. 1992), then an SEM:AVS ratio <1 indicates that acute toxicity is unlikely. The method has not yet been adapted for chronic toxicity.

Biotic Effects

Zinc concentrations in plants and animals are extremely variable. In plants, the background concentration ranges from 8 to 150 mg/kg (Bodek et al. 1988). In fish, concentrations are normally <700 mg/kg dw (Eisler 1993); based on a nationwide survey of zinc in fish, Schmitt and Brumbaugh (1990) reported a mean concentration of 21.7 mg/kg ww (about 88 mg/kg dw) and an 85th percentile concentration of 34.2 mg/kg ww (136 mg/kg dw). For both birds and mammals, normal tissue zinc concentrations are <210 mg/kg dw (Eisler 1993).

Plants

Sensitive terrestrial plants such as oak and maple seedlings died when soil zinc levels were >100 mg/kg, as shown in table 35. In general, zinc uptake by plants is promoted by low soil pH and is restrained by high soil pH, high clay content, high cation exchange capacity, or a high phosphate level in the soil (Bodek et al. 1988). The general symptoms of zinc toxicity in terrestrial plants are chlorotic and necrotic leaf tips, interveinal chlorosis in new leaves, retarded growth of the entire plant, and injured roots resembling barbed wire (Kabata-Pendias and Pendias 1992). Cereals and spinach are the common crop plants most sensitive to zinc toxicity. The recommended maximum acceptable zinc concentration in soil for terrestrial plants is 70–400 mg/kg, depending on the form of zinc and the soil conditions.

Fish

Significant adverse effects were observed in the most sensitive fish species at a waterborne zinc concentration of 10 mg/L (table 36). When larvae and alevins of rainbow trout (*Oncorhynchus mykiss*) were exposed to 10 µg Zn/L, 54 percent of them died after a 28-day exposure (Spear 1981). Acute 96-h LC50 values for salmon were measured at >1,270 µg/L (Hamilton and Buhl 1990).

Knox et al. (1982) found that rainbow trout can tolerate relatively high dietary concen-trations of zinc. There was no effect on growth or health of rainbow trout when they

Table 35.—Biological effects of zinc in sediment or soil

Species	Zn in sediment/ soil (mg/kg dw)	Zn in biomass (mg/kg dw) and other effects	Comments	Reference
Plants				
Oak (*Quercus rubra*)	100	Lethal to seedlings	Planted in culture medium	Eisler 1993
Red maple (*Acer rubrum*)	100	Lethal to seedlings		
Invertebrates				
Aquatic invertebrates	1,149	Complete absence of Plecoptera, Ephemeroptera, Odonata, Trichoptera, Amphipoda, and Unionidae	Manitouwadge Lake, Ontario, Canada	Munkittrick et al. 1991
Earthworm (*Aporrectodea tuberculata*)	28	320		Eisler 1993
	97	810		
	110	1,300		
	190	1,100		
	320	650		
	470	No worms found		
Fish				
White sucker (*Catostomus commersoni*)	43	Liver 112; muscle 25; stomach contents 7	Loken Lake, Ontario, Canada	Munkittrick et al. 1991
	1,149	Liver 210; muscle 20; stomach contents 886. Lowered growth rate	Manitouwadge Lake, Ontario, Canada	
Mammals				
Field vole (*Microtus agrestis*)	21,000	Whole body 191.6	Pb-Zn mine site	Johnson et al. 1978
	131	Whole body 121.2	Uncontaminated site	Roberts and Johnson 1978
	59	Whole body 100; liver 113; kidney 121	Uncontaminated site	Anderson et al. 1982
Shrew (*Sorex araneus*)	21,000	Whole body 141	Pb-Zn mine site	Johnson et al. 1978
Vole (*Clethrionomys glareolus*)	21,000	Whole body 123.4	Pb-Zn mine site	

were fed a diet containing zinc at a level of 683 mg/kg dw (table 37). Other feeding studies using rainbow trout found no observed effect with dietary concentrations ranging from 440 to 1,700 mg/kg dw, although progressively higher zinc concen-trations were observed in the liver, blood, and gills (Wekell et al. 1983).

Amphibians

Amphibian embryos are known to be more sensitive to zinc than older stages. As shown in table 36, most amphibians show serious adverse effects at waterborne zinc concentra-tions >1,500 µg/L. Amphibians are reported to accumulate zinc more than other species. Compared to concentrations in fish, zinc concentrations in tadpoles were 10 times as high, and those in eviscerated tadpoles were twice as high (Jennett et al. 1977).

Birds

Birds are relatively tolerant to zinc (Puls 1988; Eisler 1993). Ducks (*Anas* spp.) had reduced survival when they consumed 2,500 to 3,000 mg Zn/kg in diets. When the same amount (3,000 mg/kg) was fed to mallards (*Anas platyrhynchos*), they developed diarrhea after 15 days, leg paralysis in 20 days, and high mortality after 30 days. The lowest con-centration of zinc in diet that caused adverse effects in birds was 178 mg/kg. When 178 mg Zn/kg was fed to domestic breeding hens for 3 weeks, it caused immunosuppression of young progeny without affecting growth (Eisler 1993).

Mammals

Mammals also are relatively tolerant to zinc (Puls 1988; Eisler 1993). Most mammals can consume much higher levels of zinc than their normal intakes without showing any deleterious effects. Most studies of zinc in mammals have focused on whole-body concentrations; zinc did not bioconcentrate in liver or kidney tissue. Among the small mammals listed in table 35, the field vole (*Microtus agrestis*) was found to accumulate the most zinc in whole-body concentrations (Talmage and Walton 1991). At a soil concentration of 21,000 mg/kg dw, it accumu-lated a zinc concentration of 191.6 mg/kg dw, significantly higher than the concentrations in control voles. Many studies show that mammals generally can tolerate dietary zinc levels up to 100 times their usual daily requirement for long periods without showing significant adverse effects (Eisler 1993).

Bioaccumulation

Bioconcentration factors (BCFs) of zinc can vary greatly between freshwater species. For insects, the BCF can vary from 107 to 1,130 and for fish from 51 to 432 (EPA 1980).

Interactions

In solution, inorganic oxides and humic substances increase the bioavailability of zinc (EPA 1991, 1992). Moreover, mixtures of zinc and copper are known to be additive or "more-than-additive" in toxicity to many aquatic organisms. Finlayson and Verrue (1980) conducted long-term and short-term toxicity studies on Chinook salmon (*Oncorhynchus tshawytscha*) using various water concentrations of copper and zinc mixture. From the results, they estimated that safe levels of copper and zinc for Chinook salmon would be below 11 and 83 mg/L, respectively. Other metals that are additive to zinc in toxicity are lead and nickel. On the other hand, cadmium is known to be antagonistic to zinc. A low-molecular-weight protein, metallothionein, also plays an important role in the transport, storage, and detoxification of zinc (Hamilton and Mehrle 1986). Metallothionein synthesis is induced when most vertebrates and some plants are

Table 36.—Biological effects of zinc on aquatic species

Species	Zn in water (µg/L)	Effect	Comments	Reference
Plants				
Brown macroalgae (*Fucas serratus*)	9.5	BCF: 10,770 in 140 days	Marine algae	Eisler 1993
Freshwater alga (*Selenastrum capricornutum*)	30	Some growth inhibition in 7 days		Eisler 1993
	40–68	95% growth inhibition in 14 days		
	100	100% growth inhibition in 14 days		
Freshwater algae, most species	>1,000	Growth inhibition		Eisler 1993
Phytoplankton	15	Primary productivity reduced in 14 days		Eisler 1993
Invertebrates				
Cladoceran (*Daphnia magna*) eggs	10,000–50,000	No effect on mortality	46-h exposure. Eggs more tolerant than adults	Bodar et al. 1989
	100,000	Increase in mortality		
Mayfly (*Epeorus latifolium*) larvae	10–30	Decreased growth rate after 2 weeks. Notable increase in mortality at 4 weeks		Hatakeyama 1989
	100	Growth rate 37% of control at 1 week, near 0% at 2 weeks. All died before emergence		
	300	Growth rate 24% of control at 1 week, near 0% at 2 weeks. All died before emergence		
Midge (*Chironomus tentans*) larvae	8,200	48-h EC50 (Effect: immobilization)	Temp. 14°C, pH 6.3	Khangarot and Ray 1989
Mosquito (*Aedes aegypti*) hatched pupae	500	20% increase in mortality	pH 6.1	Abbasi et al. 1985
Snail (*Ancylus fluviatilis*) juvenile	80	100d LC50	Shell length <2 millimeters	Eisler 1993
	130	100d LC50	Shell length >3 millimeters	
Snail (*Ancylus fluviatilis*) adult	100	No adverse effect on reproduction in 100 days		
	180	Reproduction reduced in 100 days		
Snail (*Biomphalaria glabrata*) embryos	500	Survival reduced to 50%		Eisler 1993
Snail (*Biomphalaria glabrata*) adults	500	Growth and reproduction inhibited		

Table 36.—Biological effects of zinc on aquatic species—Continued

Species	Zn in water (µg/L)	Effect	Comments	Reference
Invertebrates—Continued				
Sponge (*Ephydatia fluviatilis*) adults	6.5	No effect on growth; no tolerance developed with long-term exposure		Eisler 1993
	26	After exposure for 10 days, tissue deterioration and death during 3-week post-exposure period		
Fish				
Bluegill (*Lepomis macrochirus*)	1,400	96-h LC50 (Cu present)	Cu = 400 µg/L; temp. 22±1 °C; pH 6.8–7.5	Thompson et al. 1980
	3,200	96-h LC50 (Cu absent)	Cu = 0; other conditions as above	
Chinook salmon (*Oncorhynchus tshawytscha*)	1,270	96-h LC50	In fresh water; mean weight 1.03 g	Hamilton and Buhl 1990
	2,880		In brackish water; mean weight 2.60 g	
	5,530	24-h LC50	In fresh water; mean weight 1.03 g	
	12,600		In brackish water; mean weight 2.60 g	
Chinook salmon (*Oncorhynchus tshawytscha*) eggs to hatchlings	145	28-d LC10s, based on various mixed solutions of Cu and Zn	Zn = 3× dissolved Cu	Finlayson and Verrue 1980
	175		Zn = 3× total Cu	
	224		Zn = 6× dissolved Cu	
	254		Zn = 6× total Cu	
	396		Zn = 11× dissolved Cu	
	437		Zn = 11× total Cu	
Chinook salmon (*Oncorhynchus tshawytscha*) hatchlings to swim-up fry	119	28-d LC50s, based on various mixed solutions of Cu and Zn	Zn = 3× dissolved Cu	Finlayson and Verrue 1980
	145		Zn = 3× total Cu	
	156		Zn = 6× dissolved Cu	
	187		Zn = 6× total Cu	
	208		Zn = 11× dissolved Cu	
	234		Zn = 11× total Cu	

Table 36.—Biological effects of zinc on aquatic species—Continued

Species	Zn in water (µg/L)	Effect	Comments	Reference
Fish—Continued				
Coho salmon (*Oncorhynchus kisutch*), yearling	4,600	96-h LC50	Temp. 10–12°C; hardness 68–78 *or* 89–90 mg/kg (as $CaCO_3$)	Lorz and McPherson 1976
Rainbow trout (Oncorhynchus mykiss)	10	28-d LC54	Larvae and alevins	Spear 1981
	70-140	25-d LC50	Early life stages	
Steelhead trout (*Oncorhynchus mykiss*) eggs to hatchlings	170	60-d LC10s, based on various mixed solutions of Cu, Zn, and Al	Cu:Zn:Al = 1:4:6, dissolved Zn	Finlayson and Aschuckian 1979
	200		Cu:Zn:Al = 1:4:6, total Zn	
	280		Cu:Zn:Al = 1:12:18, dissolved Zn	
	290		Cu:Zn:Al = 1:12:18, total Zn	
Steelhead trout (*Oncorhynchus mykiss*) hatchlings to swim-up fry	140	60-d LC10s, based on various mixed solutions of Cu, Zn, and Al	Cu:Zn:Al = 1:12:18, dissolved Zn	Finlayson and Aschuckian 1979
	140		Cu:Zn:Al = 1:4:6, dissolved Zn	
	170		Cu:Zn:Al = 1:4:6, total Zn	
	180		Cu:Zn:Al = 1:12:18, total Zn	
Amphibians				
South African clawed frog (*Xenopus laevis*)	>1,500	At 96 h, some mid-gut malformations and pericardial edema		Eisler 1993
	2,700	50% malformations in 96 h		
Newt (*Triturus cristatus*)	200–3,000	Newts became lethargic, ate poorly, and had skin darkening before death. Elevated Zn concentrations in kidney, brain, liver, and intestine		Eisler 1993

Table 37.—Summary of exposure-response or exposure-bioaccumulation of zinc

Species	Zn in diet (mg/kg dw)	Zn in biomass (mg/kg dw) and effect when observed	Comments	Reference
Food chain				
Mayfly (*Epeorus latifolium*) larvae	940 (algae)	No change in growth rate; slight increase in mortality		Hatakeyama 1989
	1,380 (algae)	Growth rate decreased to 55% of control within 1 week but rebounded after 2 weeks. Significant increase in mortality; impaired emergence		
	2,170 (algae)	Impaired emergence and growth rate; significant increase in mortality		
Woodlouse (*Porcellio scaber*)	5,000	Survival reduced to 74% of control		Beyer et al. 1984
	20,000	Survival reduced to 34% of control		
Slug (*Arion ater*)	<100	No significant effect		Eisler 1993
	300–1,000	Reduced food consumption at day 27		
	470	Significantly impaired growth		
Fish				
Rainbow trout (*Oncorhynchus mykiss*)	440	Liver 106; blood 171; gill 308. No effect		Wekell et al. 1983
	860	Liver 120; blood 192; gill 522. No effect		
	1,700	Liver 151; blood 244; gill 1,120. No effect		
	683	Liver 24. No effect	20-week exposure. Diet also contained 178 mg/kg Cu	Knox et al. 1982
Birds				
Mallard (*Anas platyrhynchos*)	3,000	Leg paralysis and decreased food consumption	30-day exposure	Eisler 1993
	>3,000	Many deaths		
Peking duck (*Anas platyrhynchos*)	2,500	Progressive ultrastructural degeneration of pancreatic acinar cells evident as early as day 5	56-day exposure	Eisler 1993
Mammals				
Horse (*Equus caballus*)	1,000	2,728–3,511 in liver; caused Cu deficiency		Eisler 1993
	2,000	4,364–4,524 in liver; caused Cu deficiency		
Domestic mouse (*Mus* sp.)	682	No effects		Eisler 1993
	6,820	Reduced survival, growth, and food intake		

chronically or acutely exposed to zinc and other heavy metals. It protects against the ill effects of zinc by sequestering zinc more efficiently.

Regulatory Standards

Standards and criteria established by the U.S. Environmental Protection agency are listed in table 38. For standards and criteria set by State agencies, contact those agencies directly. See Appendix I for a listing of water quality officials in the 17 Western States.

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Table 38.—U.S. Environmental Protection Agency standards and criteria for zinc

(See Appendix II for explanation of terms. Source: EPA, 1985, 1995)

Status	EPA priority pollutant; carcinogencity unknown
Drinking water MCL/MCLG	None established
Secondary MCL	5 mg/L
Drinking-water health advisories for 10-kilogram child	1-day HA: 6 mg/L 10-day HA: 6 mg/L Long-term HA: 3 mg/L
Drinking-water health advisories for 70-kilogram child	Reference dose: 0.3 mg/kg/day Long-term HA: 10 mg/L Lifetime HA: 2 mg/L DWEL: 10 mg/L
Freshwater criteria (hardness dependent)	
At hardness of 50 mg/L $CaCO_3$	65 µg/L for acute exposure 59 µg/L for chronic exposure
At hardness of 100 mg/L $CaCO_3$	120 µg/L for acute exposure 110 µg/L for chronic exposure
At hardness of 200 mg/L $CaCO_3$	210 µg/L for acute exposure 190 µg/L for chronic exposure

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